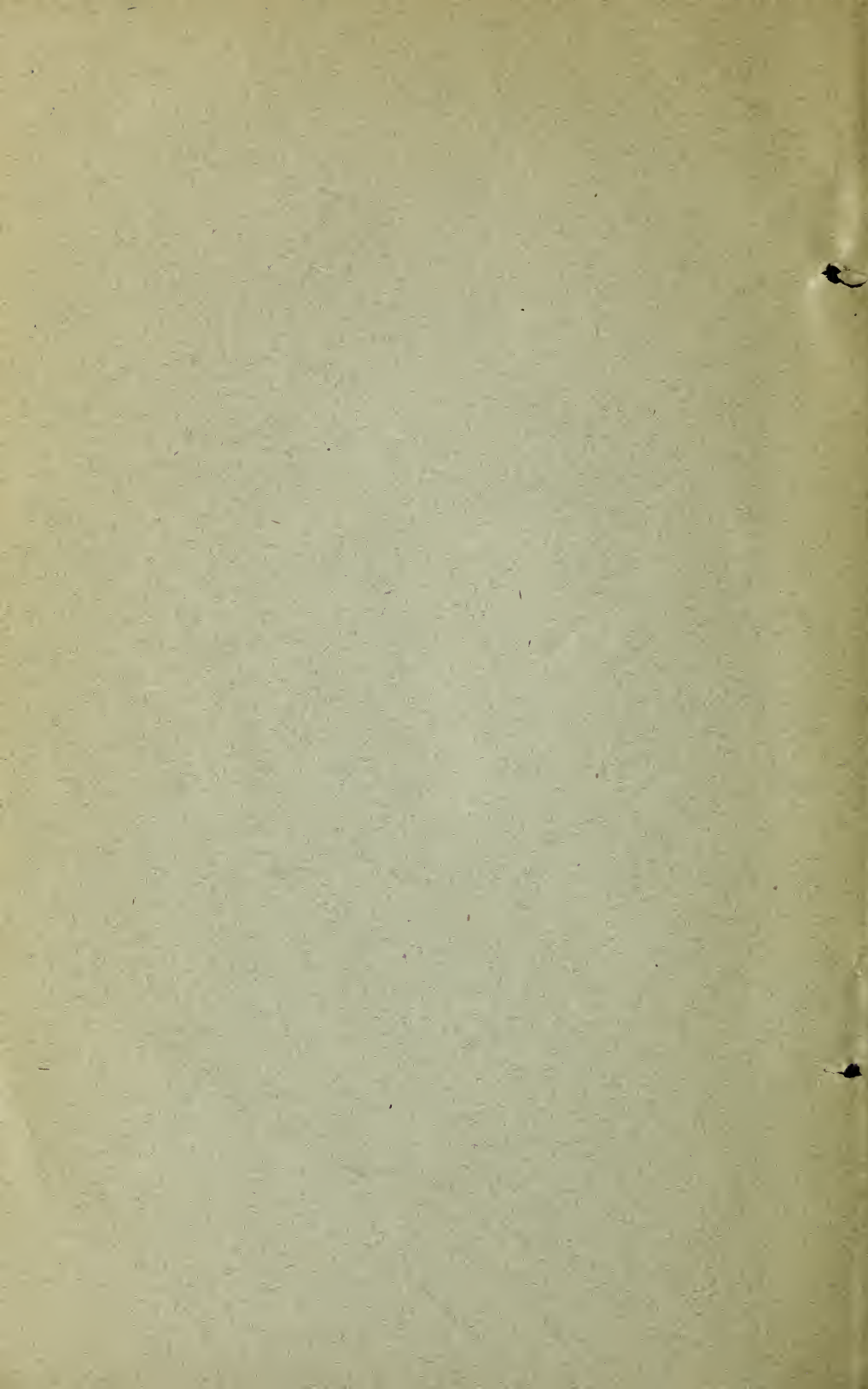


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NOTES ON A GEOLOGICAL TRAVERSE FROM
MOHAVE, CALIFORNIA, TO THE MOUTH
OF SAN JUAN RIVER, UTAH.

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ART. XX.—*Notes on a Geological Traverse from Mohave, California, to the Mouth of San Juan River, Utah;*¹
by HERBERT E. GREGORY and LEVI F. NOBLE.

During the months of August and September, 1922, a geological traverse was made from Mohave, California, eastward to a point on Colorado River opposite the mouth of San Juan River in Utah for the purpose of recording the regional relations of certain Paleozoic and Mesozoic formations previously described from disconnected localities.

From Mohave and Pilot Knob, the route lay along the south ends of Searles Lake basin, the Slate Range, Panamint Valley and Panamint Range, and crossed in turn Death Valley, the Amargosa or Funeral Range, Amargosa Valley, the Nopah Range, Pahrump Valley, the Charleston Range, Las Vegas Valley, the Muddy Range, the lower Virgin Valley, and finally the Virgin and Beaverdam Ranges,—affording a traverse entirely across the Great Basin from the Sierra Nevada to the Plateau province. East of the Beaverdam Mountains the route continued a hundred miles into the Plateau province along an irregular course. It included traverses of three long streams:—(1) Virgin River and its upper forks, (2) Kanab Creek, and (3) Paria River, from their sources nearly to Colorado River; a traverse up the Colorado from Wahweap (Sentinel Rock) Creek to the southeast end of the Kaiparowitz and along the Escalante Valley to the village of Kaiparowitz Plateau, thence across the Escalante; a traverse along the East Kaibab fold between the abandoned settlement of Paria and Kaibab (Buckskin) Gulch; and excursions to Kaiparowitz Peak, to the Paunsaugunt Plateau, to the region about Swallow Park, and to the base of Pine Valley Mountain north of St. George.

Some observations resulting from this traverse are here presented. A detailed account, containing the sections measured and a discussion of the stratigraphy, will be published later by the Geological Survey.

Between the south end of the basin of Searles Lake

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and the Avawatz Mountains at the south end of Death Valley the route followed a long straight depression trending due east that appears to be an eroded structural trough. For this depression, which does not appear to have been previously described, the name Leach Trough is proposed—a name taken from Leach Point, a prominent landmark south of a low divide in the trough. The Leach Trough coincides with a line of displacement which proves to be the eastward continuation of the great fault along the south base of the El Paso Range mentioned by Buwalda² and also by Hess,³ who called attention to recent rift phenomena upon it in the vicinity of Garlock and named it the Garlock fault. Apparently the feature as a whole constitutes one of the major structural lines of California. At it, or not far north of it, all the north-south structures of the Great Basin between the Sierra Nevada and Death Valley come to an end. The valley of Searles Lake, the Slate Range, Panamint Valley, and Panamint Range terminate abruptly at the Leach Trough, as may be seen from an inspection of the Searles Lake topographic map. The fault along the Leach Trough is well exposed at the south end of the Slate Range where Tertiary strata (probably Pliocene) that lie in the trough are faulted against the south face of the range. South of the Leach Trough lies a region of rather shapeless depressions and irregular mountain ranges whose trends do not exhibit the parallel orientation that characterizes the mountains and valleys north of the trough. This region of indefinite structural trends south of the trough is part of Mohave Desert. The Leach Trough may therefore be considered the natural northern boundary of Mohave Desert.

At the mouth of Rhodes Wash in the eastern escarpment of Death Valley, beds of very coarse pre-Tertiary breccia, mostly quartzitic, were noted. They occur in association with gneiss which has been classed as pre-Cambrian.

On the road leading from Tecopa in Amargosa Valley to Manse in Pahrump Valley, an examination was made of a series of beds that has been reported as possibly of

² Buwalda, J. P., Structure of the Southern Sierra Nevada, *Bull. Geol. Soc. Am.*, vol. 26, p. 403, 1915.

³ Hess, Frank L., Gold mining in the Randsburg quadrangle, California, U. S. Geol. Survey, *Bull.* 430, Part I, page 25, 1909.

Mesozoic age.⁴ These beds crop out in low hills along the western edge of Pahrump Valley about two miles west of a point marked "Dry Well" on the extreme northwest corner of the Ivanpah topographic map. These supposedly Mesozoic beds were found to consist chiefly of thinly laminated, brownish, reddish, and yellowish limestones, calcareous shales, and limestone conglomerates resting with marked angular unconformity upon tilted beds of Paleozoic limestone. They bear no lithologic resemblance to beds in any part of the Mesozoic section examined in the Charleston Range on the opposite side of Pahrump Valley, but on the other hand they resemble rather closely certain fresh-water limestones that constitute a part of the borax-bearing Horse Spring formation of Tertiary age exposed in the Muddy Mountains. These supposedly Mesozoic beds are not correlatives of any part of the upper Moenkopi, Shinarump, Chinle, Wingate, or Navajo; and, although the possibility exists that they represent a part of the Moenkopi not seen in the Charleston Range, or perhaps some Mesozoic formation younger than the Navajo, it is probable that they are, in part, Tertiary, and are to be correlated either with the Horse Spring formation or with one of the Tertiary formations exposed in the Amargosa and Furnace Creek regions.

Along the entire route from Mohave to Pahrump Valley the outcrops observed proved to be granitic rocks (granites, gneisses, and schists), Paleozoic sediments (gradually decreasing in amount of metamorphism from west to east), or lavas and sediments of Tertiary and Quaternary age. Some of the Paleozoic sediments are invaded by granite. No rocks were seen that in any way resemble the Mesozoic strata of the Plateau province and none have ever been reported in the region with the exception of the supposedly Mesozoic, but probably Tertiary, beds just described, and some beds in the Owens Valley region that may be correlatives of a part of the Moenkopi. Apart from these beds the Triassic section near Owens Valley described by Knopf⁵ appears to have

⁴ Spurr, J. E., Descriptive Geology of Nevada south of the fortieth parallel and adjacent portions of California, U. S. Geol. Survey, Bull. 208, page 198, 1903.

⁵ Knopf, Adolph, A Geological Reconnaissance of the Inyo Range and the Eastern Slope of the Southern Sierra Nevada, Calif., U. S. Geol. Survey, Prof. Paper 110, page 46, 1918.

no lithologic features in common with any part of the Plateau Mesozoic section. With these facts in mind the appearance in the Charleston Range of a magnificent section of Mesozoic formations, each one exhibiting the familiar lithology and topographic expression peculiar to it in the heart of the Plateau province, was startling in its suddenness. Standing on a Shinarump bench littered with fragments of petrified wood and looking up across a slope of brightly colored Chinle beds to a cliff of cross-bedded Navajo sandstone perhaps 1500 feet high, one could readily imagine himself in the region of Zion Canyon many miles northeastward in Southern Utah. So far as known, this Mesozoic section lying near the California-Nevada border constitutes the westernmost exposure of rocks classed as Shinarump, Chinle, Wingate, and Navajo, and the occurrence here of these formations in all their typical character and in practically undiminished thickness so far as the great cross-bedded sandstones are concerned suggests many interesting problems. The study of the Charleston Range now being made by D. Foster Hewett should yield large returns.

The absence of Mesozoic sandstones from the region west and southwest of the Charleston Range leads to a speculation concerning their original distribution. One wonders why, if they originally extended into California, as their great thickness in the Charleston Range seems to indicate, none of them are preserved there. The region unquestionably has suffered intense deformation by faulting, folding, and igneous intrusion since the time when the Navajo sandstone was deposited, and many masses of Tertiary strata have been preserved from erosion by these movements, so that it is difficult to understand why some of the Mesozoic sandstones have not been preserved in like manner if they once covered the region. On the other hand, geologic structures for a long distance west and southwest of Pahrump Valley are practically unknown in detail and may, when studied, afford an explanation not now suspected. Nevertheless, one is led to wonder whether the absence of the Mesozoic sandstones from the region west and southwest of Pahrump Valley does not mean that over the greater part of it they never were deposited and consequently whether a high mountain mass did not exist

there during the part of Mesozoic time that they represent.

In the Virgin River region the boundary between the Plateau province and the Great Basin lies along the eastern base of the Beaverdam Mountains and their structural continuation, the Virgin Mountains. This composite range also proves to be the division zone between two sharply contrasted types of topography. West of the crest of the range the dominant element in the landscape is the alluvial fan, which flanks or even buries peaks and ridges and everywhere forms long continuous slopes that sweep down to flat-floored alluvium-filled, intermontane valleys. East of the crest of the range alluvial fans are practically absent from the landscape and bare cliffs and intricately dissected platforms prevail. The composition of the fine-grained sandstones that constitute the prevailing rocks of the Plateau province is unfavorable for the making of alluvial fans. In weathering, these sandstones break into fragments that disintegrate so rapidly into their component grains that they form neither talus nor gravel. For example, the Mesozoic sandstone in the Charleston and Muddy Mountains do not give rise to alluvial fans and are, in aspect, bits of plateau scenery transported to the Great Basin, whereas the outcrops of hard Paleozoic limestone that border these areas are flanked by great fans.

The complexly folded and faulted Beaverdam-Virgin Range stands as a high barrier across the general course of drainage in southwestern Utah, but Virgin River flows directly through the range in a deep gorge which constitutes a remarkable physiographic feature. The course of Virgin River in this region, crossing folded and faulted Mesozoic, Paleozoic, and pre-Cambrian rocks, bears evidence of antiquity perhaps antedating that of the Colorado.

In the valleys of the middle and upper Virgin River where Permian, Triassic, and Jurassic rocks are exposed in eroded anticlines and in gorges of superposed and subsequent streams, particular attention was given to the strata between the Kaibab limestone and the Shinarump conglomerate. This assemblage of beds occupying the position of the Moenkopi formation presents features

widely variant from the type section on the Little Colorado and fully justifies the preliminary analysis made by Reeside and Bassler.⁶ As displayed in mesas and canyon walls in the region east of the Hurricane escarpment this enlarged and modified Moenkopi shares with the Navajo sandstone the honor of providing southwestern Utah with its most striking scenic features.

Field work of the past decade in southern and eastern Utah and along the Colorado canyons in Arizona, involving correlation with the well-known Kanab Creek section of Walcott, made it desirable to restudy that section with a view to ascertaining to what extent the recent divergent views represent fact and to what extent inference. Guided by the original field notes kindly furnished by Dr. Walcott, the section along Kanab Creek was remeasured from near Colorado River to the summit of the Paunsaugunt Plateau. Some recorded observations are:

1. On lower Kanab Creek near the mouth of Hacks Canyon a bed of limestone conglomerate twenty feet thick occurs in the Supai formation at the same horizon at which it occurs in the Grand Canyon (Bass Trail, Bright Angel Trail, Tanner Trail) and in the Aubrey Cliffs near Seligman.⁷ It is probable that this widespread characteristic member, which strikingly resembles the "saurian conglomerate" of the Chinle formation, has considerable stratigraphic significance and may mark a zone of unconformity.

2. The upper massive sandstone member of the Supai is much more violently and persistently cross-bedded on Kanab Creek than it is in the Kaibab division of the Grand Canyon and in lithologic composition, texture and scale of cross-bedding closely resembles the Navajo sandstone. Most of the cross-bedding is tangential.

3. The unconformity between the Supai formation and the Hermit shale, described by Noble in the Kaibab division of the Grand Canyon,⁸ is well exposed in the canyon of Kanab Creek below the mouth of Hacks Canyon. In places hollows forty feet deep in the Supai

⁶ Reeside, J. B., Jr., and Bassler, H., Stratigraphic sections in southwestern Utah and northwestern Arizona, U. S. Geol. Survey, Prof. Paper 129, pp. 53-77, 1922.

⁷ Noble, L. F., A Section of the Paleozoic formations of the Grand Canyon at the Bass Trail, U. S. Geol. Survey, Prof. Paper 131-B, page 61, 1922.

⁸ Noble, L. F., op. cit. pp. 63-64.

are filled with beds of Hermit shale. The upper 550 feet of strata classed as Supai by Reeside and Bassler in a section measured at Hacks Canyon⁹ are Hermit shale. Along Kanab Creek, as in the western part of the Kaibab division, the unconformity is coincident with the great bench or platform that Dutton has named the "Esplanade." This relation suggests the possibility that the Esplanade is an exhumed erosion surface of Carboniferous time.

4. The Coconino sandstone thins steadily northward up Kanab Canyon and disappears beneath Kanab Creek a few miles north of the mouth of Snake Gulch (Shinumo Canyon of older maps) where it is less than fifteen feet thick. Throughout its outcrop in Kanab Canyon the Coconino appears to be one bed (made up of cross-bedded wedges), not several beds, to be continuously traceable into the thick bed that represents the formation in the Kaibab division of the Grand Canyon.

5. The Coconino-Hermit contact is a well-marked spring horizon in Kanab Canyon just as it is throughout the Kaibab division of the Grand Canyon and along the western border of the Kaibab Plateau. Evidently the Hermit shale is much more impervious than the Coconino sandstone and offers everywhere a barrier to percolation. This relation may be worthy of consideration, for it is conceivable that fuller knowledge of the thickness and distribution of the Coconino will reveal geologic structures favorable for the ponding of waters in sufficient quantity to be recoverable by wells.

6. The subdivisions of the Kaibab limestone as outlined by Reeside and Bassler for the Hurricane cliff, Toroweap, and Hacks Canyon regions, are repeated on lower Kanab Creek and may be closely correlated with Noble's section of the Kaibab at Bass Trail¹⁰ except that the Harrisburg gypsiferous member, if represented at all at Bass Trail, includes but a few feet of the highest Kaibab beds exposed at Bass Trail and contains no gypsum. The middle gypsiferous member of the Kaibab, which is almost all gypsum at Kanab Creek, is represented at Bass Trail by sandstone and contains no gypsum, but beds of brecciated sandstone are common to this member

⁹ Reeside and Bassler, *op. cit.*, page 69.

¹⁰ Noble, *op. cit.*, pp. 27, 28.

at Kanab Creek, throughout the Kaibab division of the Grand Canyon, and at Kaibab (Buckskin Gulch) southwest of Paria.

7. The "Permian" fossils of Walcott were obtained from beds equivalent to the Virgin limestone member of Reeside and Bassler—strata slightly developed or absent from the Moenkopi formation east of the Paria and the Little Colorado.

8. The Vermillion Cliffs at Kanab (Chinle, in part) include the "saurian conglomerate" found by Cross in the La Plata Mountains, and within the Chinle is an unconformity probably of considerable extent.

9. The White Cliffs together with an underlying massive cross-bedded sandstone are the enlarged equivalent of the Navajo and Wingate formations of Arizona.

10. The fossiliferous Tertiary limestones forming the Pink Cliffs are underlain by a coarse conglomerate which in turn rests with angular unconformity upon a surface of considerable relief.

Search for a much desired locality in the Kaibab Plateau in which unquestionably all of the Kaibab limestone is exposed was rewarded at Kaibab Gulch (locally known as Buckskin Gulch), twelve miles southwest of the abandoned settlement of Paria. This canyon, which is cut entirely across the northern part of the plateau, exposes in the East Kaibab fold a magnificent section of the Kaibab (695 feet thick) with the Hermit shale below it and the Moenkopi above. It is proposed to use this section as the type for a redefined Kaibab formation.

The Coconino is absent from this section—an observation which taken in connection with its thinning almost to the vanishing point up Kanab creek, its presence as a thin bed (25 feet) overlying the Hermit on the West Kaibab fault at Ryan and its thickness of 300 feet near Lee's Ferry (Bryan) and of 650 feet in the lower valley of the Little Colorado, appears to mark the Coconino as a well-defined lentil which wedges out northward, northwestward and perhaps northeastward. Furthermore, the presence in the Kaibab Gulch section of massive cross-bedded sandstone in the lower part of the Kaibab but above fossiliferous limestone suggests the possibility that sandstone assigned to the Coconino in the northeastern, eastern and southeastern parts of the Plateau prov-

ince may form part of the Kaibab. A clear definition of the Coconino is obviously needed. It is perhaps significant that the thickness of the Coconino wherever observed in the Grand Canyon district is in inverse ratio to that of the underlying Hermit.

Supplementary to observations made by Gregory in 1915 and 1918, attention was given to the "Marine Jurassic" of Walcott—strata lying between the Navajo ("White Cliff," LaPlata) and the Upper Cretaceous. In the canyon of the Parunuweap near Mt. Carmel, Utah, a proposed type section of the series of formations roughly grouped as "Marine Jurassic," shows fossiliferous limestones and calcareous shales occupying the lower part of an assemblage of beds which include gypsum, sandstone, consolidated variegated muds, and lenses of conglomerate. The equivalent of the fossiliferous limestone portion (222 feet thick on the Parunuweap) was traced westward to Pine Valley Mountain and eastward to a point on Colorado River above the Crossing of the Fathers, and sections were measured at the Parunuweap, at Kanab Creek, at Dry Canyon (near Paria River), at Cottonwood Creek, and at Meskin Bar (on Colorado River). At the last two localities the thickness of the limestone is measured in inches.

In canyons tributary to Paria River and along the flanks of the Kaiparowitz Plateau the group of strata occupying the position of the McElmo (between the Navajo and the Upper Cretaceous) includes shales, gypsum, and massive cross-bedded sandstone. It exhibits surprising changes along the strike and calls for the subdivisions and interpretations such as will result from the present work of Prof. R. C. Moore. Throughout southern Utah this series of beds and that included in the Moenkopi present the greatest departure from corresponding groups in other parts of the Plateau province.

Field observations strengthened the impression gained in previous years of rhythmic deposition during Carboniferous, Triassic, and part at least of Jurassic time. In color, texture and sequence of beds, and types of unconformities the Supai and Hermit are closely similar to the Chinle, the Coconino to the Wingate and Navajo, and the Kaibab to the fossiliferous portion of the "Marine Jurassic." Part of a similar sequence of beds is repre-

sented in the Moenkopi. Even such naturally variable features as the limestone conglomerates in the Supai and Chinle and the continuously recurring cross-bedded sandstones, with laminae dipping dominantly southeast, south, rarely southwest, are strikingly alike.

Over the region from southwestern Nevada to New Mexico the Shinarump conglomerate varies considerably in texture and composition and in the character of its contact with the Moenkopi. It appears to be the coating of an arid land surface and to include materials of low grade fans, basin floors, and stream washes,—something of the nature of a desert pavement in process of construction. .

